Proceedings of the 2018 Winter Simulation Conference
M. Rabe, A.A. Juan, N. Mustafee, A. Skoogh, S. Jain, and B. Johansson, eds.

TRANSITION TO ALTERNATIVE FUEL VEHICLES: A DISTRIBUTIVE JUSTICE PERSPECTIVE

Wissam EL Hachem
Pietro De Giovanni

Operations Management Department
ESSEC Business School
3 Avenue Bernard Hirsch
Cergy-Pontoise, 95021, FRANCE

ABSTRACT

In this paper, we build a system dynamics model to investigate the ongoing endeavor to transition from conventional non-renewable transportation systems to renewable ones. The model focuses on light to mid duty vehicles in the private transportation sector. The literature focuses on the environmental and economic aspects of such a transition. We adopt distributive justice as a new angle, define it as access to transportation, justify its relevance by considering it a vital need for people to actualize their capabilities in society and propose a measure to quantitatively measure it in our context. There are several layers of tradeoffs in policy appraisal, yet we are able to catalyze the transition to AFV's while improving its sustainability. A policy that ensures such a harmonious behavior is one that focuses on the GHG emissions with little to no emphasis on the AFV quotas, while providing support for consumers to switch to AFV's.

1 INTRODUCTION

Sustainable development has become the foundation in planning for the future. Re-Conceptualization of the transportation sector is currently underway. The latter being unsustainable has attracted a lot of public attention. Its transition to a fully renewable based one has gathered most of the scientific and public support.

This paper relies on the System Dynamics (SD) methodology to investigate the transition to Alternative Fuel Vehicles (AFV) and offer insights for policy design. A system dynamics (SD) model is built to capture some of the most important feedback loops at play in such a transition. The model focuses on light to mid duty vehicles in the private transportation sector. The model investigates the impact that technological development of the electric renewable fleets coupled with marketing efforts and policy interventions would have on their market share in the future.

The literature focuses on the environmental and economic impacts arising from our current unsustainable consumption of fossil fuels. In this paper, we adopt a new and necessary angle when investigating the transition to AFV that is distributive justice. We define distributive justice following Martens et al. (2012) as access to transportation and justify its relevance following Walzer (1983) by considering access to transportation as a vital need for people to actualize their full capabilities in society.

By considering this extra dimension of distributive justice, we are not only offering a more wholesome and sustainable assessment of the AFV transition, we are as well tackling policy tradeoffs by explaining and reducing some of the noted transportation policy paradoxes in (Boussauw and Vanoutrive 2017). Our addition of distributive justice as a novel policy objective increases the operational complexity of the system and consequently creates another layer of tradeoffs between the components themselves of distributive justice (Hulle et al. 2017; Colquitt and Rodell 2015): Equity, Equality and Need. However, this extra layer of tradeoffs proves to be relatively small and the system as a whole benefits from this addition of distributive justice as seen by an overall reduction in the intensity of the tradeoffs (i.e. reduction in dysfunctional complexity) and a more swift transition to AFV's. Our results confirm that we need to consider simultaneously the environmental objective to catalyze the AFV transition while incorporating distributive justice as a social objective to constrain the transitional dynamics (from our current ICE dominated state to the desired AFV state) to remain within socially acceptable boundaries avoiding serious social repercussions which are easily avoidable in a non-zero sum system.

2 LITERATURE REVIEW

2.1 Modelling Approaches

Transition to AFV is a complex and dynamic process. Because of this complexity, Simulation models are applied in the transportation and more specifically in the vehicle adoption context (Eppstein et al. 2011; Shafiei et al. 2012; Struben and Sterman 2008; Zhang et al. 2011; Kwon 2012; Mueller and Haan 2009). An important component of these Simulation models are consumer choice models. The latter are widely used in literature to portray individual as well as group decision making. The most popular approach is the Multinomial Logit (MNL) model, which has been used to capture the preferences of consumers and translate them into the probability of choosing a specific alternative out of a given set of alternatives (Liao et al. 2017). The most common attributes to investigate consumer preferences in the adoption of AFV are: charging infrastructure availability, maintenance cost, operating cost, driving range, emissions and purchase price (Liao et al. 2017; Al-alawi 2013). Social influence plays an important role in consumer's willingness to adopt AFV's (Axsen and Kurani 2010) and is thus considered in most models.

2.2 Policies

Alternative Fuel Vehicles (AFV) are still in the early adoption phase since innovators are the main users. As any other innovation, many barriers hinder the widespread diffusion and adoption of AFV according to Bjerkan et al. (2016) ; Diamond (2009) ; Egbue and Long (2012). Examples of these barriers are: cost related such as battery/vehicle costs, technological performance related such as battery range and service related such as lack of charging infrastructure. According to Bjerkan et al. (2016), these barriers interact and reinforce each other resulting in a general lack of willingness to consider AFV.

In the literature, the different types of policies are categorized under different overlapping categories (Bjerkan et al. 2016). These policies can be broadly categorized as: Technology-Push vs Market-Pull policies (Burer 2009). Both of these types of policies have to be applied together for the renewable technologies to complete the innovation chain and survive the technology "valley of death" (Grubb 2004).

In our model, we apply different policy instruments that span the spectrum briefly presented above: GHG policies (technology neutral) to Zero Emission Vehicle (ZEV) policies (technology-specific), subsidies to AFV (positively driven) to ICE Fuel Tax (negatively driven).

2.3 Distributive Justice

The investigations carried out in the AFV literature focuses on the analysis of economic and environmental performance metrics. This literature stream disregards the concept of distributive justice in transportation policies.

However, the same literature clearly reports that individuals judge policies and make decisions by considering various justice criteria (Luo 2007; Colquitt et al. 2001). So, we have a mismatch between transportation policies objectives and the individuals' appraisal criteria when assessing these policies.

In this paper we seek to fill this gap by including the distributive justice principle in policy assessment. Distributive justice is an indiscriminate and equitable access to transportation, the latter being a vital means for people to realize their full capabilities in society (Martens et al. 2012; Walzer 1983).

2.3.1 Relevance of Justice in the Context of Transportation Policies

According to Walzer (1983), goods that do not have distinct social meaning such as expensive gold watches can and should be distributed following the free market rationale of demand and supply. Differently, goods that have distinct social meaning such as access to transportation should be governed by a "distributive justice" sphere. The latter is governed by principles such as equality and distribution on needs, and should be ruled independently from other social spheres.

Transport falls under the set of goods which do have distinct social meaning such as freedom to travel, autonomy and capability to participate in society (Martens et al. 2012); thus, it should be governed by its own distributive justice sphere.

2.3.2 Link Between Distributive Justice and the Theory of Capability Approach (CA)

According to Luo (2007) and Colquitt et al. (2001), individuals' judge policies and make decisions by considering various justice criteria. These criteria are roughly split into three dimensions: Procedural, Distributive and Interactional.

In a transportation context, we are interested mainly in the distributive dimensions of justice. Distributive justice refers to the fairness in terms of transport accessibility and activity participation capabilities of all segments of the population.

For example, Hammar and Jagers (2007) examined the perceived fairness of an increase in the CO2 tax on gasoline and diesel and found that people have preferences for fairness in policy design by supporting higher CO2 taxes, while noting that the support level was different between heavy and light car users.

The notions of fairness of capabilities and distributive justice are tightly linked with the Capability Approach (CA) theory first suggested by Sen (1985). CA has been widely adopted since then with a few applications in the context of transportation (Beyazit 2011; Ballet et al. 2013).

If a certain transportation policy changes the travel behavior of users by influencing their choice of travel mode (car, bus, bicycle), time of travel (peak hours, regular hours), distance travelled (long voyages, short commutes), then this is perfectly acceptable and is in fact the purpose of such policies. However, if a policy goes further by hindering the capability of users to participate in societal activities (work, culture, leisure…) through limiting their freedom to choose among alternatives in this choice set, then such a policy would be unjust according to CA.

2.3.3 Striking a Balance Between the Environmental and Distributive Justice Goals

According to (Harrison 2013), the current trend of car ownership is not going to change in the near to mid-term future (20-30 years) due to technological and cultural lock-in. Hence, coercive policies (limiting the choice set of users) are justified to bring down the transportation emissions and prevent tragedy of the commons (deterioration of quality of life to society as a whole due to pollution). However, where possible, such policies ought to be constrained by distributive justice principles to prevent the disproportional suffering of the worse-off (i.e. the economically worse off which are the most locked-in to current technologies such as ICE) compared to the better-off.

In the general context of green energy and environmental justice, we can talk about three overlapping principles according to Granqvist and Grover (2016): Polluter-Pays Principle (PPP), Ability-To-Pay Principle (ATTP) and Beneficiary-Pays Principle (BPP). PPP is the most straightforward in the sense that the people who pollute are responsible for fixing/remedying the damage. ATTP is more justice/egalitarian oriented in the sense that people who can afford to pay to remedy the damage done by pollution should pay regardless of whether they polluted or not. BPP states that those who benefit from the pollution, even if they hadn't themselves polluted, are responsible to pay for it since their wealth was generated on the expense of the rest of society.

A combination of PPP and ATTP would be the most realistic version to strike a balance between the distributive justice and environmental goals in the context of transportation policies (Granqvist and Grover 2016). PPP would ensure that polluters pay to compensate society for their pollution. ATPP would ensure that polluters who are incapable of reducing their pollution levels due to lack of freedom and alternatives in their choice set, would not be coerced to pay more than they are able to, leaving intact their societal participation capabilities while influencing their travel choices for the better nonetheless.

2.3.4 Tradeoffs and the Resulting Paradoxical Outcomes of Transportation Policies

Public Policies, including transportation policies, are judged according to equality and efficiency. A policy might be more efficient if targeted towards specific segments of the population (i.e. taxes on ICE vehicles; subsidies targeted to relatively financially well-off people to purchase or lease AFV), however it might lead to unjust outcomes from an equality and CA perspective. This discussion rotates around the often conflicting ideas of social welfare versus individual welfare. According to Rawls (1971), the social welfare cannot justify the overriding of individual welfare, meaning that the deprivation of certain people of some of their freedoms cannot be justified by the greater good generated to society as a whole.

Since equality and efficiency goals yield often conflicting outcomes, there is difficulty in fully upholding the ecological constraints of policy makers according to Heindl and Kanschik (2016). Ecological sustainability and its derivative concepts such as eco-sufficiency imply an upper limit of consumption with maximum policy efficiency, while distributive justice implies a lower limit of consumption.

This conflict between equality and efficiency, between distributive justice and eco-sufficiency results in paradoxical outcomes of current policies according to Boussauw and Vanoutrive (2017). Sustainable transportation policies such as imposing heavy taxes, banning older ICE vehicles and subsidizing AFV's have socially unsustainable outcomes as argued by Lucas (2012) and Boussauw and Vanoutrive (2017).

2.3.5 Research Questions

Having gone through the policy literature on the topic of transition towards AFV's and highlighted our intended contribution, we ask the following questions:

Research Question 1: How can Distributive Justice be (quantitatively) incorporated in a Model of AFV transition?

Research Question 2: What are the tradeoffs that arise when we add this extra dimension (i.e. Distributive Justice) onto transportation policy appraisal?

Research Question 3: How can we best manage these tradeoffs to achieve the best outputs on both the environmental and distributive justice objectives?

3 MODEL

The SD model captures some of the dynamics behind the transition from traditional to AF vehicles and is calibrated to the US market. Most importantly it considers the user preferences between the different types of vehicles to achieve a realistic output. The output will be the mix of different types of vehicles between 2000 and 2035. The model is built using the Vensim DSS 6.4 software.

There are 5 types of vehicles depending on the fuel they use and their size: ICE SM (Internal Combustion Engine Small to Medium sized vehicle), ICE ML (Internal Combustion Engine Medium to Large sized vehicle), H SM (Hybrid Small to Medium sized vehicle), H ML (Hybrid Medium to Large sized vehicle) and finally EV (Full Battery Powered Electric Vehicle, no size in this category). These five types are further split between New and Used Vehicles.

User preference is modelled using the cross-nested logit (CNL) choice model (Bierlaire 2006). $\sigma_{i,j}$ is the share of drivers switching from vehicle type i to type j:

$$\sigma_{i,j} = \frac{\sum_m \alpha_{j,m} x_{ji}^{1/\mu_m} \left(\sum_k \alpha_{k,m} x_{ki}^{1/\mu_m}\right)^{\mu_m - 1}}{\sum_n \left(\sum_k \alpha_{k.n} x_{ki}^{1/\mu_n}\right)^{\mu_n}}$$

Where $x_{ji} = (W_{i,j} * a_{i,j})$ is the perceived utility of platform j by current drivers of platform i, $a_{i,j} = e^{\sum_k indicator_{k,ji} * \beta_{k,ji}}$ is the Perceived utility of platform j by current drivers of platform i, $W_{i,j}$ is the willingness to consider platform j by current drivers of platform i, $\alpha_{j,m}$ is the degree that platform j belongs to nest m and μ_m is the degree of independence between alternatives within nest m.

Vehicle attributes such as price, range, emissions, and maintenance costs are part of the choice model. We chose the CNL formulation since it captures the degree of dependence μ, between relatively similar alternatives (i.e. alternatives that belong to the same nest) while allowing for one alternative to belong to more than one nest simultaneously through the α parameter. We have four nests and five different alternatives in our model. Figure 1 is a sketch of the CNL choice model.

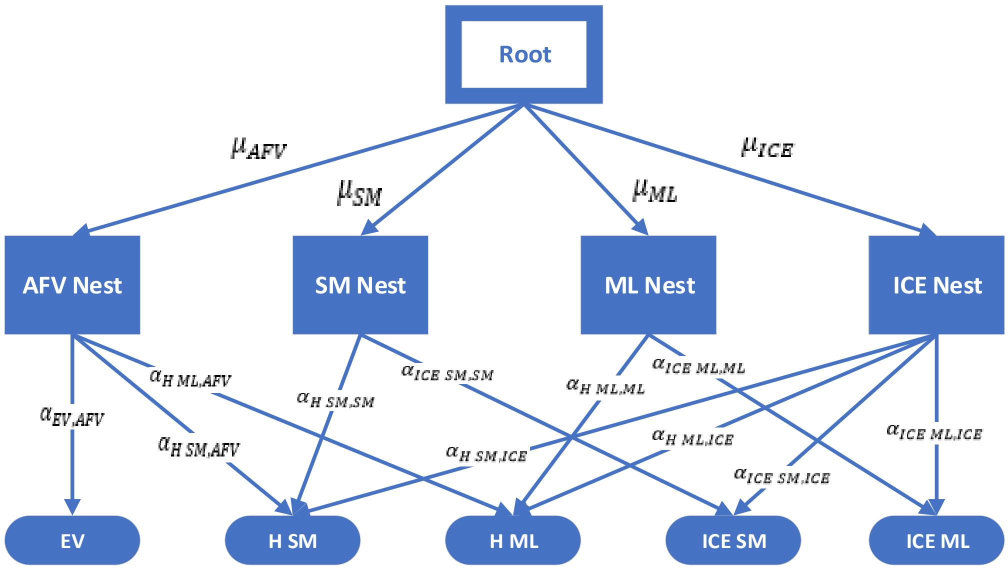

Figure 1: CNL Choice Model.

The sales of vehicles is constrained by the available supply. The supply is partly determined by the production of vehicles which is in turn constrained by the production capacity. The desired production of vehicles is determined based on a Reorder Point (ROP) which is in turn determined by a desired customer service level. Since we have a supply constraint, this means that some drivers will not be able to switch to their preferred alternative, they will instead switch to the next best available alternatives. Hence the need to allocate different sources of demand to different sources of supply. Figure 2 is a simplified diagram of the production and sales of vehicles.

The transfer of demand to available sources of supply is determined based on a heuristic that takes into consideration the different priorities of the possible demand sources as well as of the possible supply sources. These priorities are determined based on the current attractiveness of the different alternatives and their availability. Then, based on these priorities, the different types of drivers that were not able to switch to their first choice due to supply constraints are allocated to their next best available alternatives. This formulation ensures mass balance in the model.

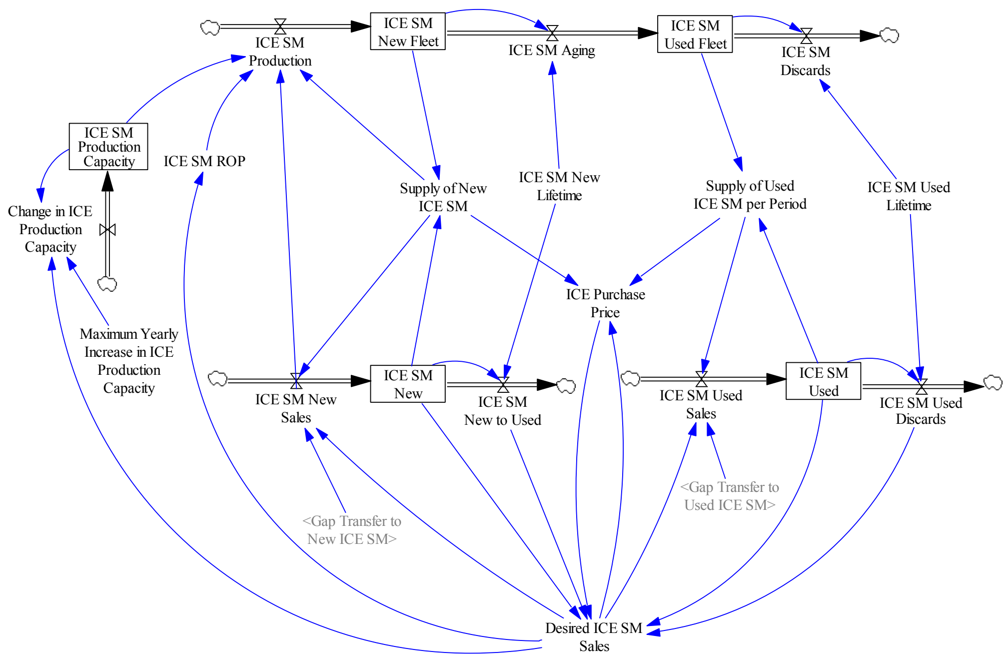

Figure 2: Production and Sales of Vehicles (This is a diagram of the ICE SM vehicle type).

The adoption decision by the drivers is based on utility maximization coupled with bounded rationality implemented via a gap between actual and perceived performance and a 'willingness to consider' factor (Struben 2008). The perceived utility of an alternative is multiplied by the 'willingness to consider' that alternative to determine its final perceived affinity. This willingness to consider captures the familiarity of the drivers with other alternatives and consequently whether they will even consider switching to another alternative.

The policy instruments used in our model are: Fuel Taxes, Green House Gases (GHG) regulations, Zero (Light) Emission Vehicles (ZEV or LEV) regulations and Subsidies as the main "Technology-specific economic" instrument.

GHG regulations are mainly targeted towards the manufacturers of vehicles to motivate them to reduce their average fleet emissions. Manufacturers can comply by either improving their ICE fleet performance, by introducing low emission vehicles (possibly mandated by ZEV regulations) or by adopting both strategies at the same time. A target fleet average emission is set by the government, and if in fact the average emissions are lower (higher) than the target, than a positive (negative) GHG credit is generated.

AFV regulations are mainly targeted towards manufacturers as well to incentivize them to introduce Low emission vehicles (LEV) in their fleets, reducing in the process the emissions. The government sets a minimum quota of low emission vehicles that has to be sold in the previous few years, usually the previous 3 years. This quota is determined by multiplying an evolving percentage of LEV (percentage set by government) with the sales of ICE in the current year or with the average sales over the previous 4th, 5th and 6th years. The sales of LEV over the previous 3 years generates AFV credits, and if the amount generated is below the minimum quota, then an AFV penalty is paid per negative credit (CARB 2017).

4 RESEARCH QUESTIONS

4.1 Question 1 - How can Distributive Justice be (quantitatively) incorporated in a Model of AFV transition?

The distributive justice has traditionally three components according to (Hulle et al. 2017; Colquitt and Rodell 2015): Equity, Equality and Need.

The equity principle (access benefits proportionally to the source of the funds) is considered in our case by minimizing the variance of the ratios of the utilities derived from the different alternatives to their respective purchase prices: $EQUITY = 1/Variance\ of\ Utility\ to\ Price\ Ratios$.

The equality principle (access benefits irrespective of the source of the funds) is taken into consideration in our case by minimizing the variance of the utility between the different alternatives: $\text{EQUALITY} = 1/Variance\ of\ Utility\ of\ Alternatives$.

The Need principle in our context is defined as providing access to the maximum number of people. It can be improved by increasing the lowest access level, with the purchase price being a proxy of the access level: $\text{NEED} = \text{Lowest Access Level} = 1/Lowest\ \text{Purchase}\ Price$.

Then, we combine all three components in one measure: $Distributive\ Justice = \sum_{i=1}^{3} Weight_i * (Component_i / Initial\ Component_i)$, where $\sum_{i=1}^{3} Weight_i = 1$.

If the distributive justice measure is equal to 1, this means that it is at the same level as its initial level at year 2000. If it increasing above (decreasing lower) than 1, then it is improving (worsening) relative to its initial level. Figure 3 below illustrates its behavior.

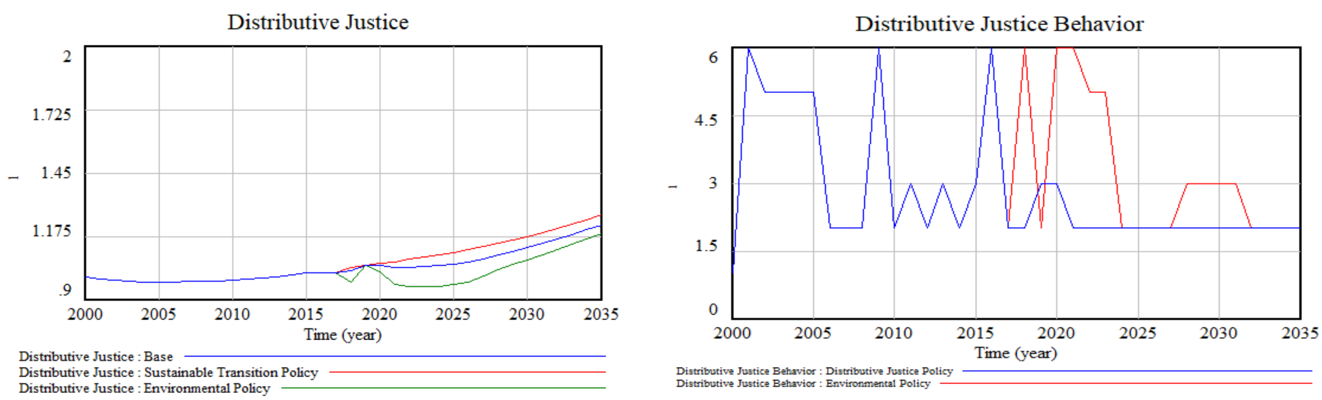

Figure 3: Distributive Justice Behavior and Tradeoffs under different policy objectives.

4.2 Question 2 - What are the tradeoffs that arise when we add this extra dimension (i.e. Distributive Justice) onto transportation policy appraisal?

There are several Layers of tradeoffs between:

1. Policy Objectives: Environmental Vs Distributive Justice
2. Distributive Justice Components: (Need, Equity, Equality) do not necessarily go hand in hand when maximizing the combined distributive justice measure

In our model, we can investigate the tradeoffs to be made between the environmental and distributive justice objectives, or between the distributive justice components themselves by numerically computing their first and second derivatives with respect to time and classifying their behavior at each point in time in 7 possible qualitative states listed below:

1. 1st derivative is zero: Objective is constant
2. 1st derivative > 0 and 2nd derivative > 0: Objective is increasing increasingly
3. 1st derivative > 0 and 2nd derivative < 0: Objective is increasing decreasingly
4. 1st derivative > 0 and 2nd derivative = 0: Objective is increasing at a constant rate
5. 1st derivative < 0 and 2nd derivative > 0: Objective is decreasing increasingly
6. 1st derivative < 0 and 2nd derivative < 0: Objective is decreasing decreasingly
7. 1st derivative < 0 and 2nd derivative = 0: Objective is decreasing at a constant rate

For example, if the behavior of the distributive justice measure at a point in time, fits into the same qualitative category whether we are maximizing it or minimizing emissions, then we can say that there is no qualitative difference in its behavior, hence no major tradeoffs are made. The two policy objectives are initially at odds. To meet the environmental goal, it is favorable to lower the utility of ICE's and increase the utility of AFV's, hence reducing overall emissions since AFV's would become relatively more attractive. This would, compared to the case where there is no active environmental policy objective, worsen both the Need component of distributive justice since it would necessarily mean higher ICE purchase prices as well as the equality component since it would widen the variance of the utilities of the different alternatives. Only when the AFV's reach a sustainable market share, around 4%, that the two goals become more or less complementary rather than opposite to each other. Figure 3 above (right half) represents the distributive justice behavior sorted into 7 possible qualitative states.

We notice that following the change in policy objective in 2018, there is some major qualitative change in the behavior of the distributive justice. It is decreasing if we minimize emissions versus increasing if we maximize distributive justice. We notice as well that starting 2024, there are no major qualitative differences in behavior since the market share of AFV would have already reached a stable level, and the two policy objectives would therefore move in harmony. Concerning the tradeoffs between the distributive justice components, we follow the same approach of computing the first and second degree derivatives of the components and classifying their behavior under 7 possible qualitative states. Prior to 2018, with regards to the environmental objective, the need component of the distributive justice indicator is at odds with the other two components. If lowest purchase price is increasing (Need is getting worse), then the equality and equity components are improving and vice versa. If we keep the same environmental policy objective, then the behavior remains more or less the same until 2027, in the sense that the need component is at odds with the other two components. Starting 2027, both the environmental and distributive justice objectives are moving in harmony, increasing together, since then the AFV market share would have reached a stable level. If we change the objective and maximize distributive justice, the behavior of the need component changes drastically. Starting 2018, the need component starts behaving almost in harmony with the other two components, by only differing in the rate at which it is increasing. This result is expected, since if we are explicitly attempting to maximize distributive justice, we can do so only when all three components are moving in harmony. Figure 4 shows the tradeoffs between the three components of distributive justice under each of the policy objectives:

Figure 4: Distributive Justice Components Behavior under each of the policy objectives.

4.3 Question 3 - How can we best manage these tradeoffs to achieve the best outputs on both the environmental and distributive justice objectives?

This question is answered by varying the strength of the different policy instruments (Tax, Subsidies, and Regulation penalties) and observing their impact given two policy objectives: Maximize AFV Sales or Minimize Fleet Emissions (i.e. keeping the same environmental objective, just varying the strength of the instruments) or Maximize Sustainable Transition to AFV. To do so, we define an operational measure that simultaneously maximizes AFV sales and distributive justice.

$$Sustainable\ Transition\ to\ AFV = \sum_{i=1}^{2} Weight_i * Change\ in\ Component_i / Max(Initial\ Component_i, Current_i)$$

If the sustainable transition measure is equal to zero, it means that the AFV transition is at the same sustainability level relative to its initial level at year 2000. If it is higher (lower) than zero, then the transition to AFV is more (less) sustainable relative to its initial level at year 2000 as seen in Figure 5:

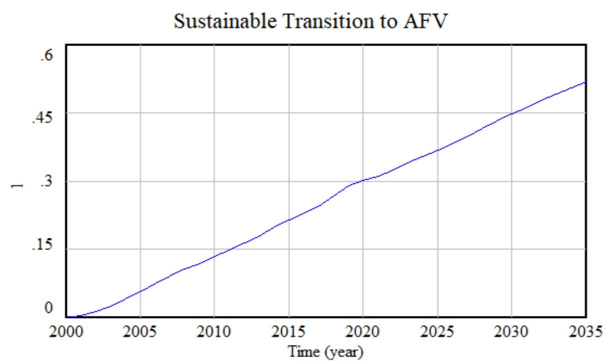

Figure 5: Sustainable Transition to AFV.

We notice that the two objectives yield drastically different results in terms of the distributive justice and the sustainable transition to AFV, yet yield similar results in terms of AFV sales (and consequently emissions), as seen in table 1 below.

Table 1: Comparison of Final Policy Scores and Instruments Strength between Our Two Policies.

		Range of Policy Instruments	Environmental Policy	Sustainable Transition Policy
Policy Scores (at 2035)	Distributive Justice	N/A	1.189	1.269
	AFV Market Share	N/A	0.1279	0.1267
	Sustainable Transition to AFV	N/A	0.506	0.533
Policy Instruments	Fuel Tax	0→0.2	0.2	
	Penalty for Emissions Gap per Credit	1000→5000	5000	
	Penalty for ZEV Gap per Credit	1000→7500	7500	1000

	Hybrid Subsidy Amount	0→5000	5000	
	EV Subsidy Amount	0→7500	7500	
	Manufacturer % Transferring GHG Penalty to Consumers	0→1	0.565	
	Manufacturer % Transferring ZEV Penalty to Consumers	0→1	1	0

We notice that the two policies result in increasing the fuel tax to the maximum, keeping the same Penalty for Emissions (i.e. relatively a large penalty), increasing significantly both the Hybrid Subsidy and the EV subsidy and increasing slightly the Manufacturer % transfer of GHG penalty to consumers.

The only major difference between the two objectives is in the ZEV penalties. In the case of the sustainable transition objective, the ZEV penalty per credit is decreased to the minimum and the Manufacturer % transfer of ZEV penalty is reduced to zero (effectively cancelling it). This makes perfect sense, since the ZEV penalty that consumers have to pay out of their pockets, from a distributive justice perspective, only worsens the need and equity components. While with the environmental objective, these two instruments are understandably increased to the maximum.

This confirms that we need to consider both the environmental and distributive justice objectives simultaneously since neglecting the latter might have social repercussions which are easily avoidable in a non-zero sum system. The policies have to focus directly on the GHG emissions with little to no emphasis on the AFV quotas, while providing maximum support for consumers to switch to AFV's. By doing so, we would catalyze the transition to AFV's while improving the sustainability of such a transition.

5 CONCLUSION

In this paper, we investigate the transition to AFV's by building a system dynamics model. We have justified the relevance of distributive justice when discussing transportation policies and defined a measure to quantitatively measure it in our context. By adding distributive justice as an extra dimension onto policy appraisal, we have introduced another layer of tradeoffs between the three components (equity, equality and Need) of distributive justice itself, however this layer was proven to be beneficial for the system as a whole since it was able to catalyze the transition to AFV's while improving its sustainability.

As the AFV market share becomes larger, the distributive justice and environmental goals start to move in harmony and the tradeoffs become minimal. This is due to the fact that policy instruments are designed with the environmental objective primarily in mind. So when the AFV share is still relatively small and unsustainable on its own, the policy instruments aggressively increase it which results in significant tradeoffs to be made with the distributive justice objective. As the AFV share grows larger, the tradeoffs between the (equity, equality, need) components become minimal, this results in distributive justice increasing more smoothly. This in turn brings the environmental and distributive justice objectives in harmony since the policy instruments are able to simultaneously increase both of them. This harmonious and beneficial behavior can be catalyzed by considering the sustainability of the AFV transition (i.e. combination of the environmental and distributive justice objectives) as our policy objective.

Our results confirm that we need to consider simultaneously the environmental objective to catalyze the AFV transition with the distributive justice as a social objective since neglecting the latter might have serious social repercussions which are easily avoidable in a non-zero sum system.

REFERENCES

Al-Alawi, B., and T. Bradley. 2013. "Review of Hybrid, Plug-In Hybrid and Electric Vehicle Market Modeling Studies". *Renewable And Sustainable Energy Reviews* 21: 190-203.

Axsen, J., and K.S. Kurani. 2010. "Anticipating Plug-In Hybrid Vehicle Energy Impacts In California: Constructing Consumer-Informed Recharge Profiles". *Transportation Research Part D: Transport And Environment* 15: 212–9.

Boussauw, K., and T. Vanoutrive. 2017. "Transport Policy In Belgium: Translating Sustainability Discourses Into Unsustainable Outcomes". *Transport Policy* 53: 11-19.

Bjerkan, K., T.E. Norbech, and M.E. Nordtomme. 2016. "Incentives For Promoting Battery Electric Vehicle (BEV) Adoption In Norway". *Transportation Research D* 43: 169-180.

Ballet, J., K.M. Koffi, and J. J. Pelenc. 2013. "Environment, Justice And The Capability Approach". *Ecological Economics* 85: 28-34.

Beyazit, E. 2011. "Evaluating Social Justice In Transport: Lessons To Be Learned From The Capability Approach". *Transport Reviews* 31 (1): 117-134.

Burer, M., and R. Wustenhagen. 2009. "Which Renewable Energy Policy Is A Venture Capitalist's Best Friend? Empirical Evidence From A Survey of International Clean Tech Investors". *Energy Policy* 37: 4997-5006.

Bierlaire, M. 2006. "A Theoretical Analysis of The Cross-Nested Logit Model". *Annals of Operations Research* 144: 287-300.

CARB (California Air Resource Board), 2017. *The California Low-Emission Vehicle Regulations, With Amendments Effective October 16, 2017*. Available: Https://Www.Arb.Ca.Gov/Msprog/Levprog/Cleandoc/Cleancomplete_Lev-Ghg_Regs_10-17.Pdf

Colquitt, J., and J. Rodell. 2015. "Measuring Justice And Fairness". In *The Oxford Handbook of Justice In The Workplace*, 1st Ed, Edited By M. Ambrose And Cropanzano, R.. New York: Oxford University Press.

Colquitt, J.A. D.E. Conlon, M.J. Wesson, C.O. Porter, and K.Y. Ng. 2001. "Justice At The Millennium: A Meta-Analytic Review of 25 Years of Organizational Justice Research". *Journal of Applied Psychology* 86 (3): 425-445.

Diamond, D., 2009. "The Impact of Government Incentives For Hybrid-Electric Vehicles: Evidence From US States". *Energy Policy* 37: 972-983.

Egbue, O., and S. Long. 2012. "Barriers To Widespread Adoption of Electric Vehicles: An Analysis of Consumer Attitudes And Perceptions". *Energy Policy* 48: 717-729.

Eppstein, M.J. D.K. Grover, J.S. Marshall., and D.M. Rizzo. 2011. "An Agent-Based Model To Study Market Penetration of Plug-In Hybrid Electric Vehicles". *Energy Policy* 39: 3789–802.

Granqvist, H., and D. Grover. 2016. "Distributive Fairness In Paying For Clean Energy Infrastructure". *Ecological Economics* 126: 87-97.

Grubb, M. 2004. "Technology Innovation And Climate Change Policy: An Overview of Issues And Options". *Keio Economic Studies* 41(2): 103–132.

Hulle, S., S. Liebig, and M. May. 2017. "Measuring Attitudes Toward Distributive Justice: The Basic Social Justice Orientations Scale". *Social Indicators Research* 136(2): 663-692.

Heindl, P. and P. Kanschik. 2016. "Ecological Sufficiency, Individual Liberties And Distributive Justice: Implications For Policy Making". *Ecological Economics* 126: 42-50.

Harrison, G., and S. Shepherd. 2013. "An Interdisciplinary Study To Explore Impacts From Policies For The Introduction of Low Carbon Vehicles". *Journal of Transportation Planning And Technology* 37(1): 98-117.

Hall, C., B. Stephen, and M. David. 2009. "What Is The Minimum EROI That A Sustainable Society Must Have? ". *Energies* 2: 25–47.

Hammar, H., and S. Jagers. 2007. "What Is A Fair CO2 Tax Increase? On Fair Emission Reduction In The Transport Sector". *Ecological Economics* 61: 377-387.

International Energy Agency (IEA). 2014. "World Energy Investment Outlook". Paris, France.

Kwon, T. 2012. "Strategic Niche Management of Alternative Fuel Vehicles: A System Dynamics Model of The Policy Effect". *Technological Forecasting and Social Change* 79(9): 1672–1680.

Liao, F., E. Molin, and B. Van Wee. 2017. "Consumer Preferences For Electric Vehicles: A Literature Review". *Transport Reviews* 37(3): 252-275.
Lucas, K., 2012. "Transport and Social Exclusion: Where Are We Now? ". *Transportation Policy* 20: 105–113.
Luo., Y. 2007. "The Independent and Interactive Roles of Procedural, Distributive, and Interactional Justice In Strategic Alliances". *Academy of Management Journal* 50(3): 644-664.
Martens, K., A. Golub, and G. Robinson. 2012. "A Justice-Theoretic Approach To The Distribution of Transportation Benefits: Implications For Transportation Planning Practice In The United States". *Transportation Research A* 46: 684-695.
Mueller, G., and P. Haan. 2009. "How Much Do Incentives Affect Car Purchase? Agent-Based Micro Simulation of Consumer Choice of New Cars, Part I: Model Structure, Simulation of Bounded Rationality, and Model Validation". *Energy Policy* 37(3): 1072–1082.
Rawls, J. 1971. “A Theory of Social Justice”. Cambridge, MA: Belknap Press of Harvard University Press.
Shafiei, E., H. Thorkelsson, E.I. Asgeirsson, B. Davidsdottir, M.Raberto, and H.Stefansson. 2012. "An Agent-Based Modeling Approach To Predict The Evolution of Market Share of Electric Vehicles: A Case Study From Iceland". *Technological Forecasting and Social Change* 79: 1638–53.
Struben, J., and J. Sterman. 2008. "Transition Challenges For Alternative Fuel Vehicles and Transportation Systems". *Environmental and Planning B: Planning and Design* 35: 1070-1097.
Sen, A. 1985. "Well-Being, Agency and Freedom: The Dewey Lectures 1984". *Journal of Philosophy* 82(4): 169–221.
Walzer, M., 1983. *Spheres of Justice: A Defense of Pluralism and Equality*. 1st Ed. New York: Basic Books.

AUTHOR BIOGRAPHIES

WISSAM EL HACHEM is a PhD candidate in the operations management department at ESSEC Business School, France. His research focus is on supply chain management, environmental management, organizational performance, decision making and lean manufacturing. His e-mail address is wissam.elhachem@essec.edu.

PIETRO DE GIOVANNI is associate professor of Operations Management at ESSEC Business School, France. He holds a PhD in Operations Management and Decision Sciences from ESSEC Business School. His research and teaching interests range from supply chain and operations management to environmental management. He has published in several scientific journals such as Journal of Operations Management, European Journal of Operational Research, Transportation Research, Annals of Operations Research and several others. His email address is pietro.degiovanni@essec.edu.